ft^3 per day for eastern North Carolina. The total volume of the digester should equal the minimum treatment volume except where waste storage is included in the design. The digester storage volume does not need to account for rainfall except for partially covered digesters. Design of a covered digester can include higher loading rates than for a typical anaerobic lagoon and a lower hydraulic retention time (HRT), which means the volume of the digester can be lower than for an anaerobic lagoon, and the size of the cover can be smaller. Normally, covered digesters should maintain a constant volume by having an overflow into a storage unit. The storage unit could have a permeable cover or an impermeable cover to reduce ammonia emissions from the storage unit.

Temperature effect: A covered lagoon or digester will operate without added heat at the ambient temperature of the liquid, which typically varies from about 40ºF to 90ºF (about 5ºC to 32ºC). Cooler temperatures reduce biogas production, so the biogas production is seasonal for ambient-temperature covered lagoons or digesters. Safley and Westerman (1994), in lab studies with swine manure loaded at 6.2 pounds VS per 1000 ft^3 per day, reported an increasing biogas production rate from 6.8 ft^3/lb VS added at 50ºF to 8.2 ft^3 per pound VS added at 68ºF.

The temperature variation could be buffered somewhat by adding insulation to the cover, but adding insulation also makes the cover more complex and results in higher costs. If insulation is utilized and heat is added, it is possible to keep the liquid temperature in the mesophilic temperature range (95ºF to 104ºF) (35ºC to 40ºC) and obtain higher biogas production using a lower HRT, perhaps 20 to 30 days. Because the temperature is kept as constant as possible, the biogas production should be essentially constant per unit of organic matter loaded. However, because the weight of the pigs and the manure production rate varies, the organic matter loading will likely vary, and thus the biogas production will vary accordingly to the loading rate.

Volatile solids loading: Actual volatile solids loading may differ from estimated volatile solids production in ASABE (2005) and NRCS (2008) tables. Loss of VS could occur in the barn or in pump stations, either from degradation or from accumulation of solids in corners or areas of low mixing. Data collected for flushed swine manure on one feeder-to-finish farm (Westerman, 2007) indicated that measured VS was approximately 50 percent less than ASABE (2005) table values of VS production. For existing farms, flow rates should be determined and samples of the flushed manure should be taken and analyzed to calculate a VS loading rate. Also, the VS loading will vary with size of pigs. The live weight of pigs will vary on many farms, especially for "all-in, all-out" farms, and this should be considered for changes in loading rate and for calculating an average loading rate.

Case Studies of Covered Digesters

Reports have been released for three covered digesters constructed in N. C. that were designed for flushed swine wastes. One digester was on a 4,000-sow farrow-to-wean farm with pull-plug shallow pits (Cheng et al., 2004) (See Figure 1), and was designed to be deeper than a typical lagoon in an attempt to maintain a higher temperature in the winter and reduce the amount of area covered per unit volume. Another digester was on a 1,000-sow

Figure 1. Ambient-temperature covered digester at 4000 sow farrow-to-wean farm in Johnston County, N.C. Cover was installed in 1998.

Figure 2. Covered lagoon at Black Farms near Lillington, N.C. Cover was installed in 2008. Cover has ports for recycle lines for flush water and irrigation pump intake as well as a pipe system across bottom of lagoon for removing sludge. Two lagoons for 6000 finishing pigs were covered.